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Art III.—*The Physiography of the Echuca District.*

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Contents.

I. Introduction.

At first sight the wide-spread plains of northern Victoria and southern Riverina do not suggest physiographic problems, but closer examination shows several interesting features in the area of which the town of Echuca is the centre. The most evident of these features is the great bend the Murray River makes to the south when about 30 miles north-east of Echuca, but this is only one of many associated features which give a physiographic unity to the district.

The area treated in this paper is a strip about 70 miles long, extending from south-east of Rochester (Victoria) to Deniliquin (N.S.W.). The width of the more important part of the strip is only a few miles, though for its study a greater area has to be included in the northern part so that the general map has something of the shape of a tau cross.

II. Previous Workers.

As far as the writer is aware no general account of the area has been published. Gregory (1) in his Geography of Victoria mentions the bend of the Murray to the south and explains it by saying that the river has here cut through the raised flood plain which borders it further east. The problem is more complex than this explanation would lead one to infer.

The New South Wales Lands Department has published a plan of part of Riverina District, extending from Wagga to Balranald, on a scale of 4 miles to the inch. Generalized contours are shown at vertical intervals of 5 feet and provide a key to

the understanding of the area. On the Victorian side the State Rivers and Water Supply Department has prepared parish plans of irrigable districts with 1-ft. contours and with spot heights shown to 1/100 ft. at intervals of 5 chains or closer if necessary. These plans, on the scale of 20 chains to the inch, are as accurate as could possibly be desired for the study of drainage problems since they have been prepared for that special purpose. From their vertical scale the plans necessarily cannot represent higher areas but in such areas detailed levels are not required for our present purpose. The fact that plans can be prepared on such a scale gives a good idea of the general flatness of most of the area. In one part—north of Corop and north-west of Lake Cooper—no detailed survey was made as this part of the district was unsuitable for irrigation, the northern portion especially being low-lying and swampy.

It is possible that among the professional papers of the Victorian Water Supply Commission there may be reports which contain information or theories regarding the area but I have seen none.

Many of the physiographic features of the Victorian portion of the area, such as the condition of Lake Cooper when settlement first reached the district, the low banks of the Murray at Barmah, and the course of streams across the line of the Bama sand-hill are mentioned in an account of early settlement written by E. M. Curr (2) who made several journeys from Colbinabbin to the Murray River nearly a century ago and who was the first settler on the lower Goulburn.

III. Acknowledgments.

I wish to acknowledge my debt to the N.S.W. Irrigation Commission (Sydney) for the map of Riverina already mentioned, and to the engineers in charge of the Victorian Water Supply Districts of Rochester (Mr. H. E. Harding) and Tongala (Mr. C. Gallop) for assistance with plans and for giving me the benefit of their thorough—and probably unique—knowledge of the drainage of those districts. My attention was directed to the study of the subject by a conversation some years ago with Mr. A. S. Kenyon.

As on every other occasion when I have needed assistance, Mr. W. Baragwanath, Director of the Geological Survey of Victoria, and his officers have done all in their power to help me. This help has been particularly valuable in the preparation of the plans, etc., which accompany this paper.

IV. General Physiography.

A glance at a map of south-eastern Australia shows that the Murray River marks a very definite drainage line. Its southern tributaries flow into it more or less at right angles, though usually directed downstream (particularly in the case of the Goulburn)

GENERAL MAP OF ECHUCA AREA

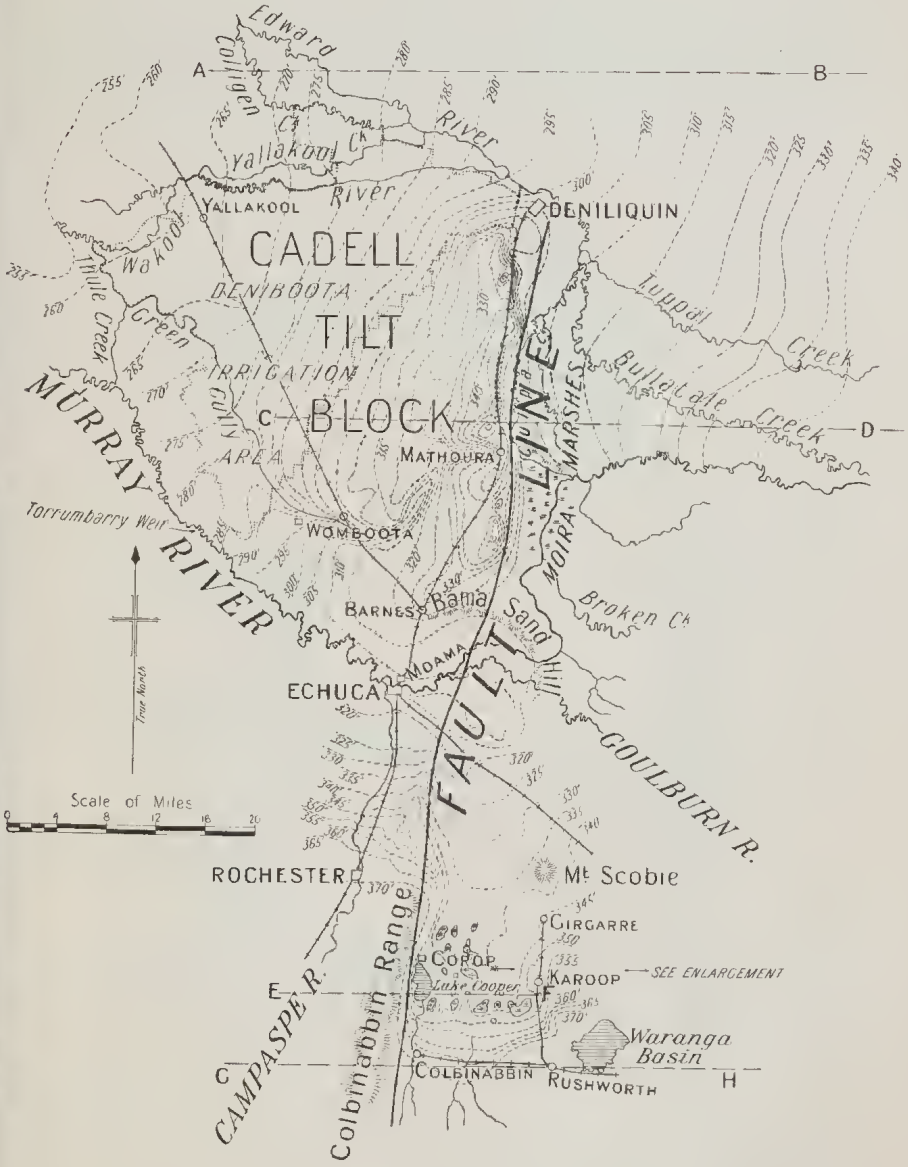

FIG. 1.

before actually entering it. North of the Murray the general direction of tributaries is from east to west and the Murray has numerous distributaries, some of which are permanent streams, while others flow only after the level of the main river has been raised by heavy rains or the melting of snow on the hills around its sources. The general direction of the contour lines in Victoria is east-west and in New South Wales north-south. In Victoria the general direction of these lines is broken by the presence of old rocks forming low hills between the various tributaries. Thus besides the hills which divide the upper Murray or Indi from the Mitta Mitta and the Mitta Mitta from the Ovens, we have the granite and Ordovician hills of which Futter's Range is the most prominent separating the Ovens from the Broken River, a spur of Silurian and older rocks between the Broken and Goulburn Rivers, culminating in the diabases and associated rocks of the Dookie Hills, the Colbinabbin Range between the Goulburn and Campaspe and the granite masses of the Terricks, Pyramid Hill and Mount Hope between the Campaspe and the Loddon. A minor spur runs parallel to the Colbinabbin Range but further east and is important for our present paper as it forms the eastern boundary of the Lake Cooper drainage basin. It is composed of the Silurian hills of Rushworth and is represented about sixteen miles further north by the isolated hill of Mount Scobie, also probably Silurian, which rises like an island above the level of the surrounding plains.

Several striking features break the regularity of the Murray plains :—

(1) The Murray River, east of Mathoura (N.S.W.), gives off two important distributaries to the north—the Edward River and Gulpa Creek—and then at the "Mathoura Bend" turns to the south as a stream of altered character till it approaches the Goulburn when it again takes a westerly course.

(2) West of this north-south reach and of the Gulpa Creek which continues the line to the north is a raised area 30 feet and more above the streams and sloping gently to the west. Not a single stream crosses it.

(3) East of the edge of this "Cadell Tilt-block" is an area of swamps and lagoons, interspersed with low sand ridges—the Moira Marshes—through which the Murray flows.

(4) South of the Murray the drainage from a large area between the Campaspe and Goulburn Rivers fails to establish a definite drainage channel to the Murray, and collects in Lake Cooper and its associated swamps making its way to the Murray in wet seasons either through ill-defined water courses or through artificial channels.

(5) Between the Lake Cooper area and the Campaspe River the Colbinabbin Range runs from south to north forming the western boundary of the Lake Cooper basin, which is separated

from the Goulburn basin to the east by the Rushworth Hills, and, further north, by a divide rarely recognizable in the field.

V. The Cadell Tilt-Block.

This name is applied to the triangular area of land between the Edward and Murray Rivers, the eastern base rising from the Murray River and Gulpa Creek, the southern side bounded by the Murray below Echuca and the northern by the Edward River and ana-branches which meet the Murray round the apex to the west

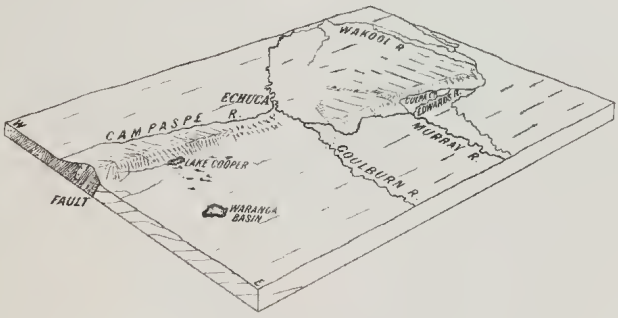

FIG. 2.- Block diagram of Area.

E. S. Hills Photo. *E. D. Service del.*

FIG. 3.—Culpa Creek south of Mathoura, showing steep bank on the western side.

From Yarrawonga to a point a few miles east of Mathoura the Murray pursues a general westerly course. It is very tortuous and cut-off meanders in all stages of evolution may be noticed. A good example is "Nine Panel Bend," a few miles upstream from the offtake of the Edward River. The "nine panel" refers

to the length of fencing necessary to cross the narrow neck of land round which the river meanders. At Yarrawonga and Tocumwal the critical stage of flood level of the Murray is over 20 feet above the cease-to-flow level. Below Tocumwal cuttings through the right bank of the river divert water into the Tuppal and Bullatale (locally Bullatella) Creeks, which ultimately join the Edward River near Deniliquin. As the little settlement of Tarragon is approached the banks of the Murray become lower and outlets through them, though small, become more numerous. At last, just east of Tarragon, a large channel, though small compared with the Murray, breaks out to the north, doubling back somewhat as it leaves the parent stream. This is the Edward River. It widens into a sluggish stream as it flows north, and at last turns west-north-west around the northern edge of the Cadell Tilt-block. The distance from where it leaves the Murray to its most northern point near Deniliquin is about 30 miles in a straight line. About a mile downstream from the Edward off-take the Gulpa Creek also leaves the Murray. At first its banks are steep and its channel deep, narrow, and canal-like. Then it expands into the Gulpa Swamp, and for about 4 miles it has no defined channel other than a shallow artificial cutting through the centre of the swamp. Near Mathoura it again becomes a wide muddy shallow creek with low ill-defined eastern banks, but steep, in places vertical, western banks (Fig. 3). After a tortuous northerly course it joins the Edward south of Deniliquin.

From the off-take of the Gulpa to the Mathoura Bend the Murray is still tortuous, but its banks are low, and the variation between high and low water levels throughout the year would be about 10 feet. Although the banks are low, floods rarely cover them continuously, and the even level of water throughout the year permits the growth of willow trees along the banks, making of these reaches a beauty spot.

About 2 miles west of the Gulpa off-take the Murray swings to the south. For over 20 miles it retains its low banks, but is narrow and comparatively straight. From its narrowness and shallowness the stretch between the Gulpa and Barmah is known to rivermen as the "little river." It is bordered by swamps which receive water through numerous small breaks in the bank of the river. The larger swamps, though shallow, may retain water throughout the whole year, and are known as the Moira Lakes both on the Victorian and New South Wales sides. Near Barmah the river regains its earlier character and turns west towards Echuca, being joined by the Goulburn River 7 miles east of the town.

The area between the Murray and Edward Rivers, as has been already stated, is crossed by no streams. The surface soil is a yellowish loam or clay though there are areas of grey loam

and some sandy rises. Its present undulating surface is partly due to modifications caused by rain wash, but there are well-marked tortuous depressions with a general east-west direction. The best-marked of these is shown on the map, trending south-west from near Mathoura, then north-west past Womboota, and ultimately merging into Thule Lagoon which is connected with the Murray. Where this depression is best shown it is a wide shallow valley with relatively steep sides, and with every appearance of being a disused, partly infilled river course. It is known locally as Green Gully.

The 350-ft. contour line runs along the eastern edge of the Tilt-block through Mathoura where the uplifted block reaches its greatest height—over 360 feet above sea level. The general height of the eastern edge of the block may be taken as 340 feet. Upstream along the Murray the 340-ft. contour line crosses the river near Tocumwal, 30 miles east of Mathoura. At the western edge of the Tilt-block the height is about 260 feet. The discussion of the significance of these features is postponed till later in the paper.

VI. The Moira Marshes.

The area between the Bullatella, Gulpa, and Murray, and the corresponding area on the Victorian side of the Murray is a region of sand ridges and swamps though there are considerable areas of relatively high land with a loamy soil. The numerous creeks are sometimes bordered by narrow banks above flood level, but on the other hand often widen into swamps and form a maze through which only an experienced bushman can find his way. The sand ridges are striking features in such country and seem often to be independent of the present drainage system. They will be briefly referred to later. Many of the swamps are apparently deserted stream courses, but others are wide expanses such as the Moira lakes which represent the lowest portions of a depressed area.

VII. The Colbinabbin Range and Lake Cooper.

The Colbinabbin Range stands out prominently on the geological map of Victoria, its colour, green for Heathcotian, showing up distinctly. The published maps show it as ending east of Elmore, but this is incorrect and mss. corrections are shown on some old maps. The rocks of the range may be traced on the low hills for some miles further north and are buried below the surface soil of the plains east of Rochester.

The geology of the range is not important for our purpose but as no account of it has yet been published, except for the part near Heathcote, a very brief summary of the geology of the northern part may be given.

The core of the range consists of diabase and cherty shales placed by Thomas (3), who has studied these rocks near Heathcote, as Middle Cambrian or older. On the west between Elmore and Colbinabbin (west of Allot. 122, Runnymede) shales yielded spicules of Protospongia (Harris and Thomas). These are the only fossils yet found in the area. Along the western side of the range fine-grained mudstones and cherty shales predominate, apparently of the Goldie Series (Upper Cambrian) of Thomas (3, p. 92).

These are well shown in road cuttings near Allots. 119, 130, and 206B, Corop, and in the north-west of Allot. 174, Nanneella. The diabase core of the range is in places massive and undecomposed as around Mount Burramboot (Allots 1, 5, Burramboot, and 40, Colbinabbin). The slopes of the range west of the Burramboot East state school show (quarry in Allot. 23, Burramboot and west of this) a succession of interbedded cherts and diabase, the latter being little altered on the hill slopes, but weathered to a greenish clay in the quarry. Near by, fragments of what may originally have been ash can be found. Jasper is a common associate of the diabase and is well shown along the north-south road between Allots. 63 and 65, Corop, and in the extreme north-west corner of the Parish of Burramboot. Fragments are common at other localities as in Allot. 7B, Corop.

The eastern slope of the Colbinabbin range is much steeper than the western and, lying about 2 miles east of the crest and 200 feet or more lower, is Lake Cooper, a shallow sheet of brackish water about 4 square miles in area. It receives the drainage of the Cornella Creek from the south but has no permanent outlet. It is only the largest of a number of similar depressions, most of which dry up in summer. In winter and after a succession of heavy rains the water level in Lake Cooper rises but most of the surplus water, instead of overflowing to the north, takes a parallel course east of the lake through an ill-defined series of swamps, and finally reaches the Goulburn or the Murray through channels partly natural and partly artificial. In fact the present drainage is regulated largely by a series of channels cut for the purpose. The Wanalta Creek further east uses the same intermittent drainage channels but has no lake along its course. It is a coincidence that the creek flowing into Lake Cooper is the Cornella (on some maps, Corneela), the main flood channel is the Cornelia Creek, while just across the Murray are Coronalla parish and Cornalla or Canally Station—all probably variants of the same native word.

The eastern boundary of the Lake Cooper-Cornella Creek depression is the "Rushworth Pene-plain" of Silurian rocks. Due north, rising as a hummock from the level and swampy plain is Mount Scobie, a low sandstone hill on which the writer obtained a few indeterminate corals, crinoid and brachiopod fragments which enable one to place it as almost certainly an outlier of the Rushworth beds.

North-west of Lake Cooper the edge of the higher country is represented very accurately by the main Waranga-Mallee irrigation channel which, through the mapped area, runs between the 375- and 365-ft. contours till it crosses the Campaspe River north of Rochester. Even further north, to within 5 or 6 miles of Echuca, the western edge of the depressed area is noticeable from the contour lines, which for over 10 miles north of the Waranga-Mallee channel near Rochester still run north and south and close together though showing a slope of only 10-20 feet. The wider divergence of these lines immediately to the north-east of Rochester is due to the fact that the Campaspe River breaks out across this stretch of country in flood time, using the Cornelia Creek channels for its surplus water.

VIII. Origin of the Lake Cooper Drainage Basin.

The swamps around and including Lake Cooper may be divided into two classes. Most of them, including Lake Cooper itself, occupy the lowest parts of the drainage areas of creeks flowing from higher ground further south—depressions which the water must fill before it finds its way further north—but some cannot be explained in this way. In the north-west of the Parish of Carag Carag and the north-east of the Parish of Corop are depressions which receive only local drainage but which are noticeably lower than the general level of the surrounding country. The best marked of these depressions are the Salt Lake, Green's Swamp, and an unnamed group of swamps in Allots. 38-40 and 50-53, Carag Carag. These are seemingly not connected with the main drainage problem, and the theory now to be advanced to account for the formation of the whole depression is strengthened by the existence of these isolated areas 20 feet or more below the general level.

It is suggested that two causes have operated in forming this region. Firstly, it is postulated that there has been down-faulting in recent times of the area east of the Colbinabbin Range. No direct evidence of faulting is visible here though further south near Heathcote faulting has been an important factor in determining rock relationships. There is no evidence that any of the Heathcote faults are recent; in fact most of them are geologically old and have no physiographic effect saving that which arises from the unequal hardness of strata. However near Bendigo (4) and west of Guildford (5) comparatively recent movement has been demonstrated to have taken place along old fault lines.

The unsymmetrical slopes of the Colbinabbin Range, as shown in the section (Fig. 6), and the low level of Lake Cooper and its drainage basin, as compared with both the Campaspe on the west and the Goulburn on the east, seem to point to factors other than normal erosion. The Campaspe at Elmore is 430 feet above sea level, the Goulburn to the east is 384 feet, while the swamps

around Lake Cooper are at 340 feet, the surface of the lake a few feet lower, Salt Lake at 320 feet (and isolated) and the general

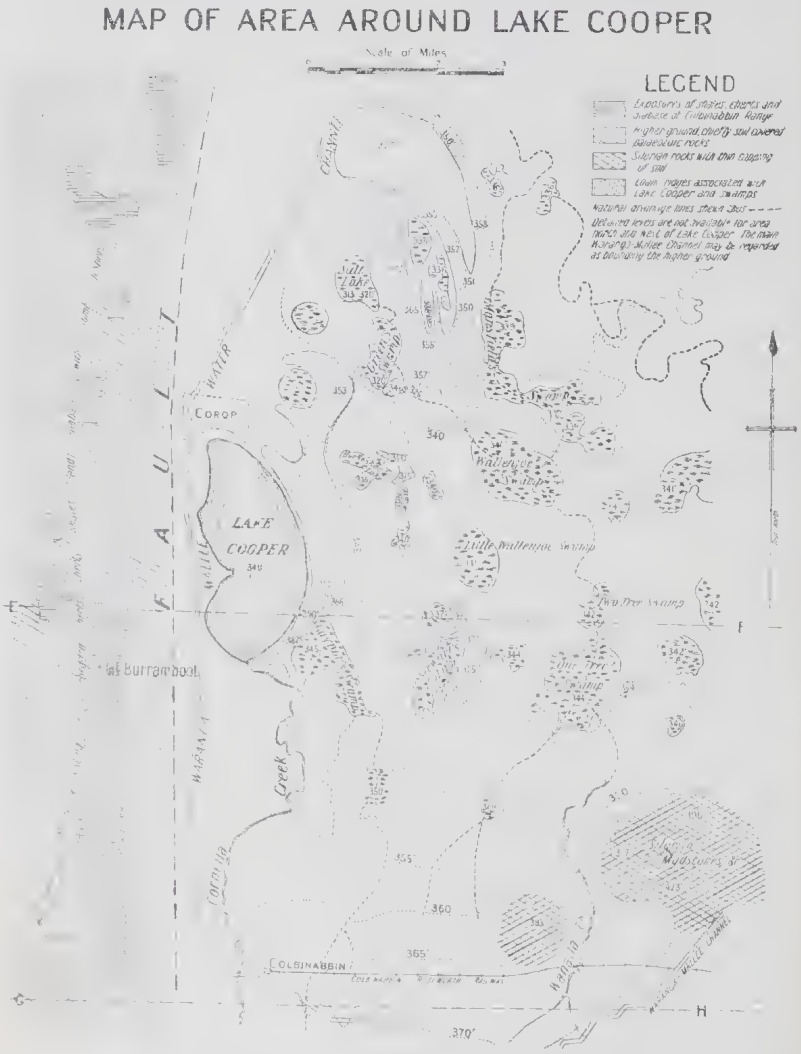

Fig. 4.

level of the surrounding plains between 340 and 350 feet. Lake Cooper is thus about 100 feet below the level of the Campaspe River at Elmore.

The physiographic features just described both south and north of Echuca can be explained if a south-north fault is postulated as running from west of Lake Cooper north to Deniliquin. In the south the result was the down-faulting of the Lake Cooper basin by perhaps 50-100 feet or even more. In the north the

Cadell Block was raised and tilted downwards to the west, the throw of the fault here being rather less than further south. Near Echuca where the movement hinged, as it were, there was little displacement and so the water of the Murray was enabled not only to find its way round the north of the raised block, but also to find its way round the south. For purposes of reference this fault may be referred to as the Cadell Fault. North-south faults are of common occurrence in northern Victoria, and at least in the two cases already mentioned—the Whitelaw fault east of Bendigo and the Muckleford Fault west of Guildford—recent movement along such a fault line seems proved. The present case would be a third example of this.

IX. Swamps in the Lake Cooper Depression.

While faulting is probably the chief agent in forming the Lake Cooper depressed area it does not fully account for some local features. These are depressions surrounded by loam ridges and not connected with the main drainage system. The best examples occur north-east of Corop. To examine this area the Corop-Stanhope road may be followed for about 3½ miles east from Corop, and a turn north then made between Allots. 93 and 94, Carag Carag. A shallow channel from the Wallenjoe Swamp

W. J. Harris Photo. *E. D. Service del.*

FIG. 5.—Lake Cooper from Colbinabbin Range. Mount Burramboot on extreme left (looking north-east).

crosses the road and, running to the north-west, enters Green's Swamp through a gap in a loam ridge. The ridge on either side of the gap rises to a height of 30 feet or more above the general level. The gap is steep-sided, but why a stream should cut such a gap is not evident since the swamp it drains had apparently another and easier outlet to the north-east. Following the road north one crosses the loam ridge which here bifurcates, one branch running to the north-east and the other slightly west of north. After the ridge is crossed a descent is made to an enclosed depression which contains three small swamps. These are merely

the lowest portions of the depression and derive their water from the surrounding slopes. The road passes through the centre of one swamp and, among the material ploughed up to form the road, may be seen nodules of earthy limestone. The presence of these nodules suggests that the actual position of the swamps may have been partly determined by the removal of limestone from the subsoil by solution, and the consequent sinking of the surface. Similar nodules occur round Lake Cooper itself and also around Salt Lake, and in other parts of the district.

The loam or clay ridges are difficult to explain and no satisfactory explanation occurs to the writer. The ridges rise to a height of 50 feet or more above the depressions in some cases, and are not composed of sand but of a yellow or brown clayey loam which when dry crumbles easily, but when wet would form a sticky mass. In addition to those already referred to an almost semicircular ridge flanks the eastern edge of a swamp in Allot. 107, Corop. (This swamp when dry is a practically level area of brackish silt.) The best marked ridge flanks the eastern edge of Lake Cooper (Fig. 4). It may be that these ridges are composed of silt blown from the depressions by west winds during a former long arid period, but this explanation does not seem fully satisfactory. The presence of remains of large trees in the bed of Lake Cooper, especially in the northern part, would indicate that the lake, if not formerly dry altogether, must for long periods have been smaller than at present, but since white settlement in the district a hundred years ago it seems to have contained water in most years. When E. M. Curr first traversed its bed in 1841 he described it as a grassy plain of wild carrot (2). P. Chauncy, in a letter to Brough Smyth dated 1873, brought under my notice by Mr. W. Baragwanath, states that he saw the lake dry in, he thinks, 1858, but his mention of this one instance would imply that this was very unusual. Old residents state that oat crops have been sown on the lake floor, and there is a report that it was dry about 1930. Large dead red gum trees (Eucalyptus rostrata), not yet stripped of small branches, are also found in the present channel of the Edward River east of Mathoura. A study of the lakes and associated loam ridges of the Kerang-Swan Hill district may throw light on the origin of the Lake Cooper ridges. Apparently similar silt hills are found on the southern and eastern sides of many of the shallow lakes in the Camperdown district, and are mentioned in Memoir No. 9 of the Geological Survey of Victoria. They are explained (p. 9) as being formed by silt blown from the dry beds of these lakes in summer. The explanation given there of the enlargement of Lake Colongulac may apply to Lake Cooper.

The Salt Lake occupies the lowest part of a depression even lower than Lake Cooper, and with a barely perceptible slope. The amount of brackish water varies according to the season, but the slope is so gentle that a sample of water free from mud cannot be

obtained without wading into the water. The shores of the lake are littered with fragments of earthy limestone as already mentioned, so that it is feasible to suppose that in this and other cases the actual position of the deepest portion of a depression may have been determined by solution. Like Lake Cooper, Salt Lake was probably often dry till irrigation channels were made through the district.

X. Sand Hills and Gravel Deposits.

Insufficient work has been done on this subject to warrant a lengthy discussion. The following facts may be stated:—

(1) Gravel deposits apparently derived from granitic rocks and not thoroughly waterworn occur at several localities, the best-known in the Echuca district being about 2 miles north of Moama, the New South Wales township on the opposite bank of the Murray to Echuca. This particular deposit is roughly stratified, and is comparatively free from iron staining. It may represent the partially re-sorted capping of a buried granitic mass such as Mount Hope or Pyramid Hill. As far as can be ascertained its thickness has never been proved by boring, possibly because the deposit, which is used for road-making purposes, could not be worked profitably below the level of the water in the Murray near by. Similar gravels, usually ironstained, are found in many places along the Murray, but are usually limited in extent, and most likely are coarse river-gravels. I have heard it stated that a bore a few miles south of Mathoura bottomed on granite at a depth of possibly 200 feet or so, but I have been unable to verify the statement which in itself does not seem at all improbable.

(2) Sand hills of much finer iron-stained material are widely distributed. They are antecedent to the present drainage system and are possibly records of an earlier more arid period. The sand consists chiefly of small fragments of glassy silica and is evidently wind-borne. The evidence shows that these deposits are older than the present river courses as the Murray, Goulburn, and Campaspe all cut through sand-hills. The best-marked ridge is known as the Bama Sand-hill, a ridge which runs for about 7 miles in a generally easterly direction from near the Barnes railway station on the Echuca-Deniliquin railway to the Murray west of Barmah (Victoria). It there turns to the south, crosses the Murray into Victoria, and is continued across a depression near Madowla, and then across the Goulburn. E. M. Curr (2) marks the Victorian part of this ridge on his map as the "Towro Sand-hill," and states that he had often speculated on the reason for its independent direction, but he gives no indication of his conclusions. The Bama Sand-hill is only the most prominent of a number of similar ridges, a second ridge being cut through by the Goulburn just before it enters the Murray, and a third being

cut by the Campaspe and Murray near Echuca. These sand hills are quite distinct from the Lake Cooper loam ridges. Before leaving this topic attention may be called to the sand ridge which flanks the northern edge of the Gulpa Swamp. (For such ridges to flank swamps is not at all unusual.) This is composed of similar material to the Bama Sand-hill, but is lower. It, too, seems to be older than the low-lying land which encloses it, and its continuation is possibly to be found in loamy ridges south and south-west of Mathoura. These, being on the raised side of the Lake Cooper-Cadell fault line, have been denuded so that the material exposed at the surface is a sandy loam rather than sand.

XI. Physical Features and Irrigation.

The structure of the area has determined the course of irrigation channels through it. The Waranga Basin, fed from the Goulburn River, commands the area in Victoria between the Murchison-Colbinabbin railway on the south and the Goulburn River on the north, but as the level of the Basin is shown as 388 feet above sea level, it will be seen that it was necessary to make the main western channel skirt the Colbinabbin Range, so that it runs almost due north from Colbinabbin to a point east of Rochester, and then turns once more west. Water from it is unavailable for the district west of the range and south of Rochester.

In New South Wales the Cadell up-lift makes irrigation impracticable by gravitation for any but limited areas of the western portion of the Cadell Tilt-block, but a scheme is at present being worked out by which a supply of water, diverted from the Murray River at Yarrawonga, will be led across the Edward River at Deniliquin and made available for the western and lower portion of the area. The eastern boundary of the proposed irrigation area roughly follows the 300-ft. contour line, but with the necessary fall. The scheme is known officially as the Deni-Noota Domestic and Stock Water Supply and Irrigation Scheme, the name being derived from the districts of Deniliquin and Womboota, though it would appear that only a small portion of the Womboota district will be in the irrigable area.

XII. Summary of Geographical History of the Area.

It is possible to construct a theory which will account for all the major geographical anomalies of the district, such as the Moira Marshes, the Cadell Tilt-block, and the inefficient drainage of the Lake Cooper region. The following is the suggested order of events.

(1) The Murray at an earlier period flowed west past Mathoura, probably just to the south of the township, and then across what we have called the Cadell Tilt-block. The depression

shown by the contour lines (Green Gully) marks this former course, and a detailed map would probably show minor tributaries and "lagoons" such as fringe the Murray at present. The large sand ridge north of the Gulpa swamp would be on the northern bank of this former stream and probably extended further west than it can be traced at the present day.

(2) Movement took place along a north-south line from near Deniliquin to somewhere near Toolleen (north of Heathcote) forming the eastern edge of the Cadell Tilt-block and the western edge of the Lake Cooper basin. It is probable that the changes were effected by a number of small displacements, possibly spread over a long period, and that the final result was that in the north the western block was raised and tilted rather than that the eastern side was depressed, as the Moira Marshes are not lower than the plains a few miles north of Deniliquin. In the south the result was the lowering of the Lake Cooper basin. Near Echuca there seems to have been little movement so that the Murray was able there to find its way across the fault line. The raising of the Echuca-Deniliquin block dammed back the Murray and formed the Moira Marshes. The Murray, faced with an obstacle right across its former course, divided, some of the water working to the north along the scarp till it found a way round in that direction, and some working to the south with the same ultimate result. The Edward, the Gulpa, and the "little river" would thus originate after the uplift. If the rainfall of northern Victoria averaged 4 or 5 inches a month the Moira Marshes would probably be converted into a shallow lake comparable with Lake George (New South Wales). That the area between Rushworth and the Colbinabbin range is a structural valley formed by sinking seems to be indicated by its low level. Even with a greater catchment and heavier rainfall it would probably be water-logged as the fall between Lake Cooper and the Murray at Echuca is only about 30 feet as compared with over 60 feet in the shorter distance between Rochester and the Murray along the line of the Campaspe. The surface of Salt Lake is practically at the same level as the banks of the Murray at Echuca.

(3) When the Murray flowed across the Cadell Tilt-block the Echuca-Koondrook stretch of the present Murray was possibly the lower course of its present tributary the Goulburn, though there is some evidence that the old Green Gully stream was joined by a large southern tributary west of Moira (New South Wales). As a result of changes of level the "little river" was formed, and the combined Murray-Goulburn then adopted the present main channel.

(4) The actual position of Lake Cooper and some of its associated swamps has been partly determined by the removal of calcareous material from the subsoil by solution, a process which led to local subsidence.

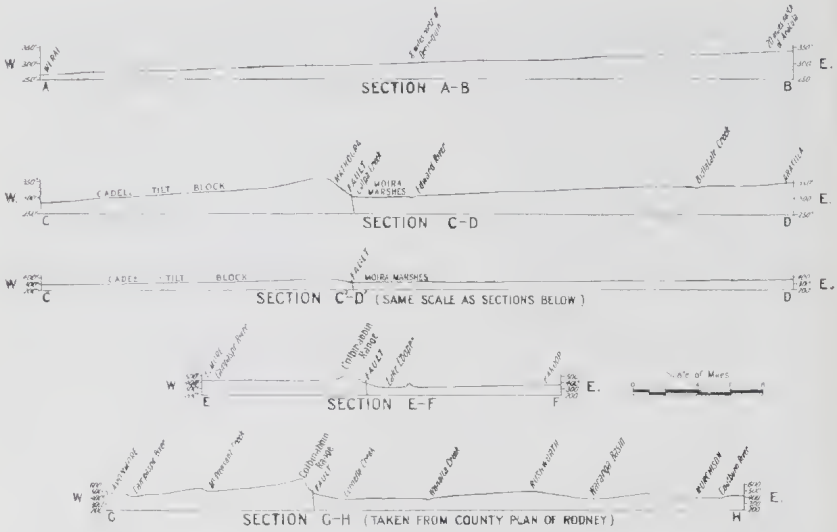

FIG. 6.—Profiles along section lines indicated in Fig. 1. All section lines are drawn to the same horizontal scale, but owing to the greater differences of elevation in the southern portion of the area the vertical scale of the two northern sections is greater than that of the two southern sections. For comparison Section C-D is drawn to both scales.

Section A–B.—This west-east section represents the general slope of Riverina north of the Edward River and beyond the influence of the Cadell Fault. The heights at both A and B are approximately the same as at C and D on the next section, but the slope is gradual and unbroken.

Section C–D. Parallel to Section A–B but further south, showing the two similar slopes into which the general slope further north has been divided by the uplift.

Section C^1–D^1 is a repetition of Section C–D on the vertical scale used for the Lake Cooper sections.

Section E–F runs from Elmore across the Colbinabbin Range and Lake Cooper to the Rushworth-Girgarre railway at Karoop. The generally higher level of the western area, the drop to Lake Cooper, the loam ridge east of the lake and the featureless plain further east are shown. No figures are available for the height of the Colbinabbin range which is almost certainly higher than shown on this section.

Section G–H from Avonmore to Murchison has been drawn from heights recorded on the county plan of Rodney at approximately 1-mile intervals. Here again the height of the Colbinabbin range is underestimated as the plan gives heights along a road which passes through a gap in the range so that the highest reading on the plan is 1 mile west of the main ridge (626 feet). On the line of the range itself 588 feet is recorded, but the range is at least 100 feet above this. The difference in level between the eastern and western portions of the section is well shown. Near Rushworth Silurian rocks outcrop and the country rises generally.

XIII. Bibliography.

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